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REPRESENTATIVE OPERATING CHARTS OF PROPELLERS TESTED IN THE NACA 20-FOOT PROPELLER-RESEARCH TUNNEL

By W. H. Gray and Nicholas Mastrocola

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE RESTRICTED REPORT

REPRESENTATIVE OPERATING CHARTS OF PROPELLERS TESTED IN THE NACA 20-FOOT PROPELLER-RESEARCH TUNNEL

By W. H. Gray and Nicholas Mastrocola

Extensive tests of full-scale propellers have been made in the 20-foot propeller-research tunnel (PRT) at the Langley Memorial Aeronautical Laboratory during its many years of operation. The results were usually presented in the form of charts showing thrust coefficient, power coefficient, and efficiency, each plotted separately against V/nD. The type of chart now being employed by airplane and propeller manufacturers for performance estimates consists of power coefficients plotted against V/nD with lines of constant efficiency superimposed. As a result of numerous requests to issue this type of chart directly and on a large scale, the present report has been compiled from data taken from a series of fairly recent reports. Charts are presented only for the conditions considered to be useful in present-day design (see table I), although charts covering other conditions have been developed and are available.

In the preparation of the plots presented, the data were cross-faired and do not necessarily check exactly the previously published data. The power coefficients of all dual-rotating propellers in this report represent the sum of the power coefficients of the front and rear propellers and are for the test conditions in which blade angles of the front and rear propellers were set to absorb approximately equal power at peak efficiency only.

The usual coefficients and symbols have been used and are defined as follows:

C_P power coefficient $\left(\dfrac{\text{engine power}}{\rho n^3 D^5}\right)$

C_T thrust coefficient $\left(\dfrac{\text{effective thrust}}{\rho n^2 D^4}\right)$

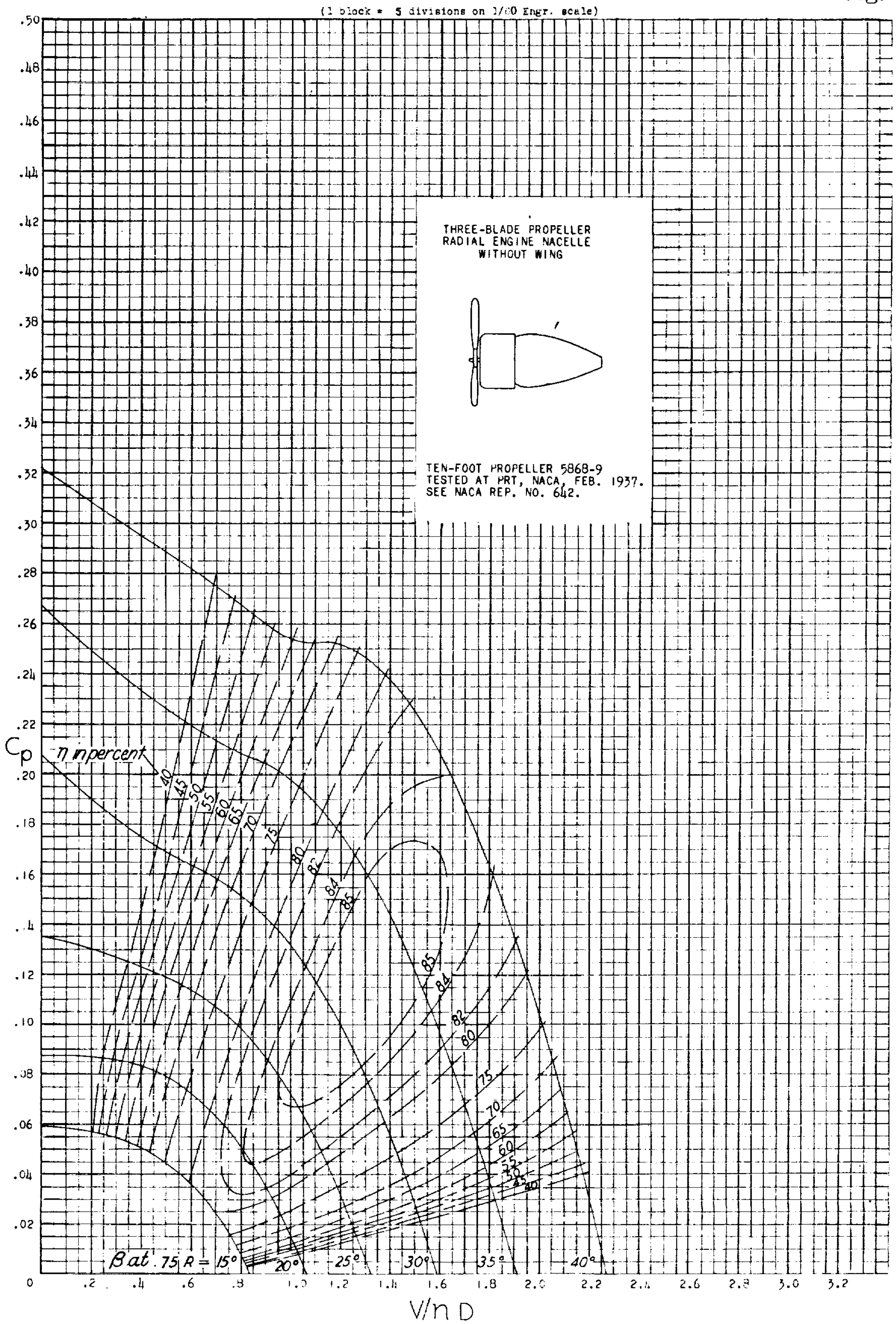
η propeller efficiency $(C_T/C_P)\ (V/nD)$

and

ρ mass density of air, slugs per cubic foot

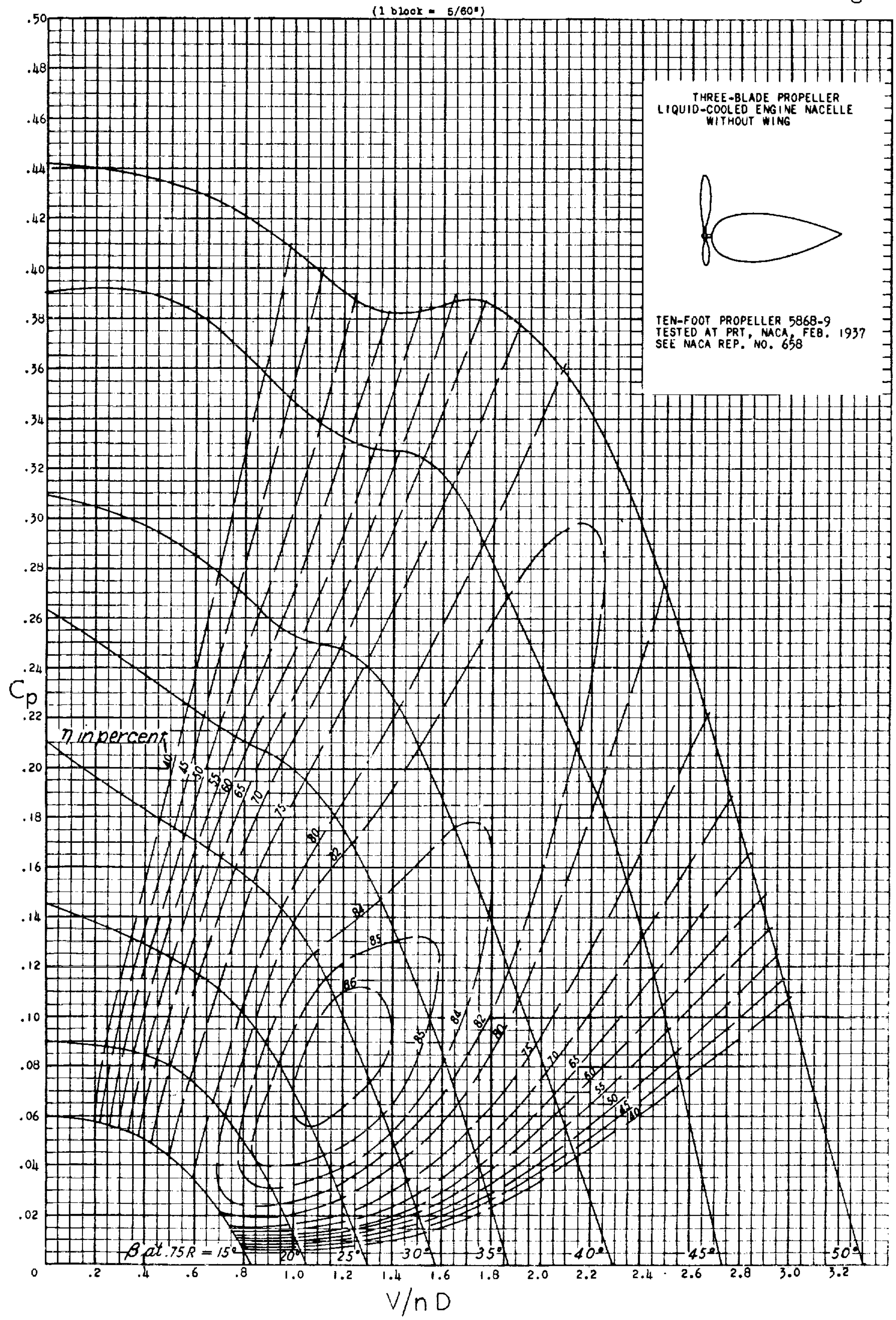
Figure	Blade activity factor	Number of blades	Rotation	Propeller location	Body configuration	Reference
					Blade design, Bureau of Aeronautics 5868-9	
1	80	3	Single	Tractor	Radial-engine nacelle without wing	Biermann, David, and Hartman, Edwin P.: Tests of Five Full-Scale Propellers in the Presence of a Radial and a Liquid-Cooled Engine Nacelle, Including Tests of Two Spinners. Rep. No. 642, NACA, 1938.
2	80	3	--do--	--do---	Liquid-cooled engine nacelle without wing	Biermann, David, and Hartman, Edwin P.: Tests of Two Full-Scale Propellers with Different Pitch Distributions, at Blade Angles up to 60°. Rep. No. 658, NACA, 1939.
					Blade design, Hamilton Standard 3155-6 and 3156-6	
3	90	2	Single	Tractor	Streamline nacelle without wing	Gray, W. H.: Wind-Tunnel Tests of Single- and Dual-Rotating Tractor Propellers at Low Blade Angles and of Two- and Three-Blade Tractor Propellers at Blade Angles up to 65°. NACA A.R.R., Feb. 1943.
4	90	3	--do--	--do---	---------do---------	Biermann, David, Hartman, Edwin P., and Pepper, Edward: Full-Scale Tests of Several Propellers Equipped with Spinners, Cuffs, Airfoil and Round Shanks, and NACA 16-Series Sections. NACA A.C.R., Oct. 1940.
5	90	3	--do--	--do---	Streamline nacelle with wing	Gray, W. H.: Wind-Tunnel Tests of Single- and Dual-Rotating Tractor Propellers at Low Blade Angles and of Two- and Three-Blade Tractor Propellers at Blade Angles up to 65°. NACA A.R.R., Feb. 1943.
6	90	4	--do--	--do---	---------do---------	Biermann, David, and Hartman, Edwin P.: Wind-Tunnel Tests of Four- and Six-Blade Single- and Dual-Rotating Tractor Propellers. Rep. No. 747, NACA, 1942.
7	90	4	--do--	--do---	---------do---------	
8	90	6	--do--	--do---	---------do---------	
9	90	8	--do--	--do---	---------do---------	Biermann, David, and Gray, W. H.: Wind-Tunnel Tests of Eight-Blade Single- and Dual-Rotating Propellers in the Tractor Position. NACA A.R.R., Nov. 1941.
10	90	3	Single	Pusher	Streamline nacelle without wing	Biermann, David, and Gray, W. H.: Wind-Tunnel Tests of Single- and Dual-Rotating Pusher Propellers Having from Two to Eight Blades. NACA A.R.R., Feb. 1942.
11	90	4	--do--	--do---	---------do---------	
12	90	6	Dual	--do---	---------do---------	
13	90	8	--do--	--do---	---------do---------	
					Blade design, Hamilton Standard 3155-6-1.5 and 3156-6-1.5	
14	135	3	Single	Tractor	Streamline nacelle with wing	Biermann, David, Gray, W. H., and Maynard, Julian D.: Wind-Tunnel Tests of Single- and Dual-Rotating Tractor Propellers of Large Blade Width. NACA A.R.R., Sept. 1942.
15	135	4	--do--	--do---	---------do---------	
16	135	6	Dual	--do---	---------do---------	
17	135	8	--do--	--do---	---------do---------	

L-286


(1 block = 5 divisions on 1/60 Engr. scale)
THREE-BLADE PROPELLER
RADIAL ENGINE NACELLE
WITHOUT WING
TEN-FOOT PROPELLER 5868-9
TESTED AT PRT, NACA, FEB. 1937.
SEE NACA REP. NO. 642.
C_p
η in percent
β at .75 R = 15°
20°
25°
30°
35°
40°
V/nD

982-7

L-286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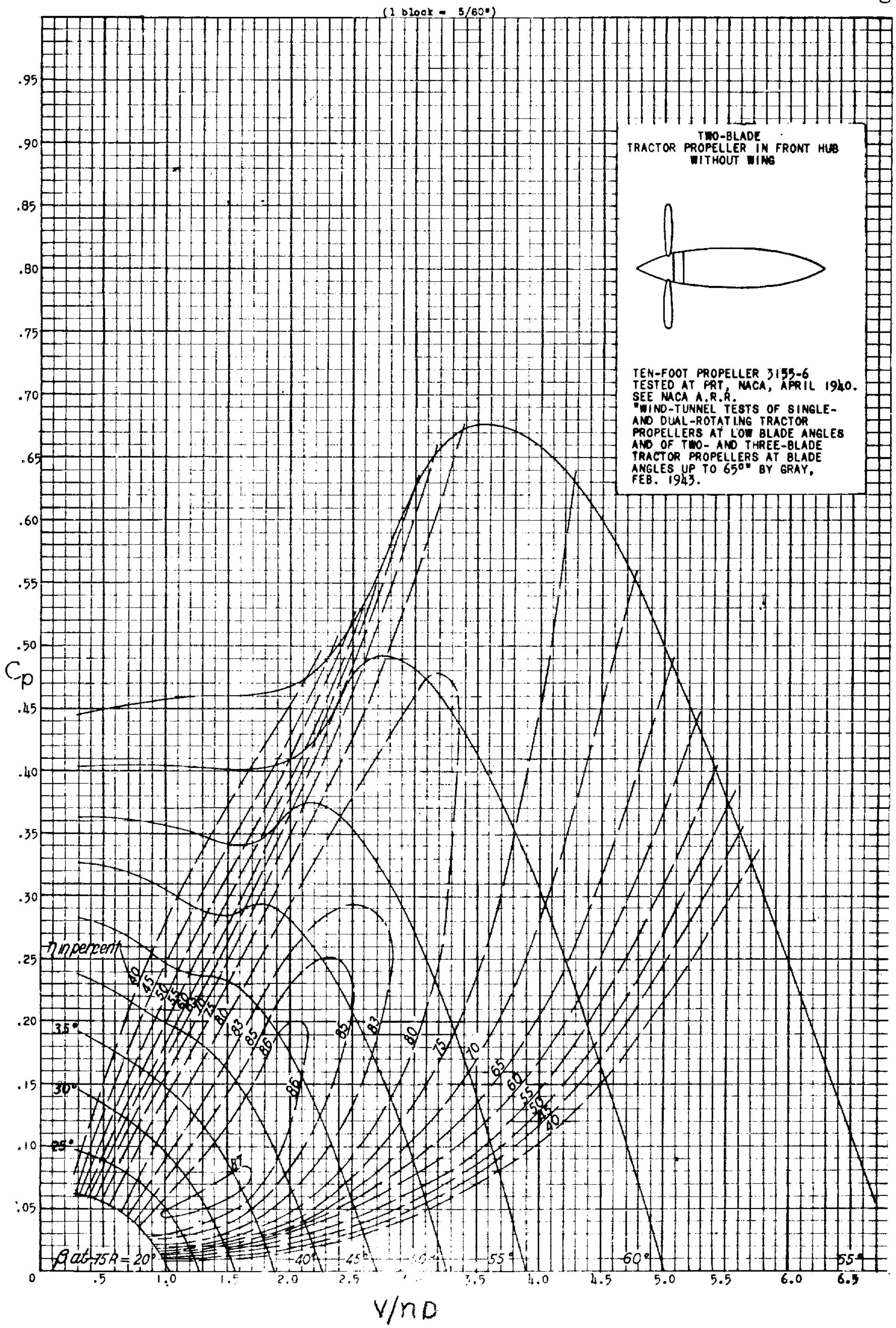
THREE-BLADE PROPELLER
LIQUID-COOLED ENGINE NACELLE
WITHOUT WING
TEN-FOOT PROPELLER 5868-9
TESTED AT PRT, NACA, FEB. 1937
SEE NACA REP. NO. 658
Cp
η in percent
β at .75R = 15°
20°
25°
30°
35°
40°
45°
50°
V/nD

L-286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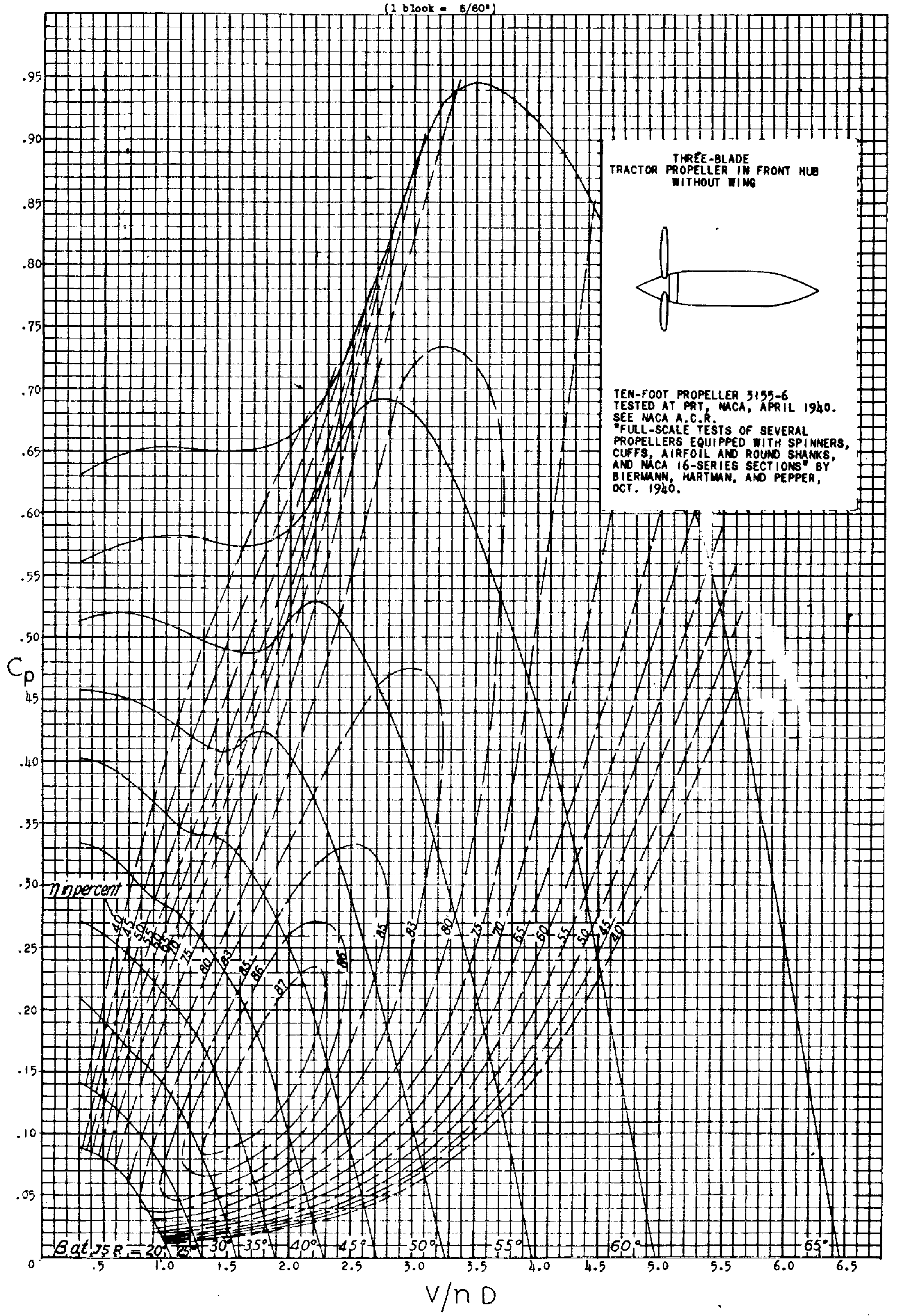
TWO-BLADE
TRACTOR PROPELLER IN FRONT HUB
WITHOUT WING
TEN-FOOT PROPELLER 3155-6
TESTED AT PRT, NACA, APRIL 1940.
SEE NACA A.R.R.
"WIND-TUNNEL TESTS OF SINGLE-
AND DUAL-ROTATING TRACTOR
PROPELLERS AT LOW BLADE ANGLES
AND OF TWO- AND THREE-BLADE
TRACTOR PROPELLERS AT BLADE
ANGLES UP TO 65°" BY GRAY,
FEB. 1943.
Cp
η in percent
β at .75R = 20°
V/nD



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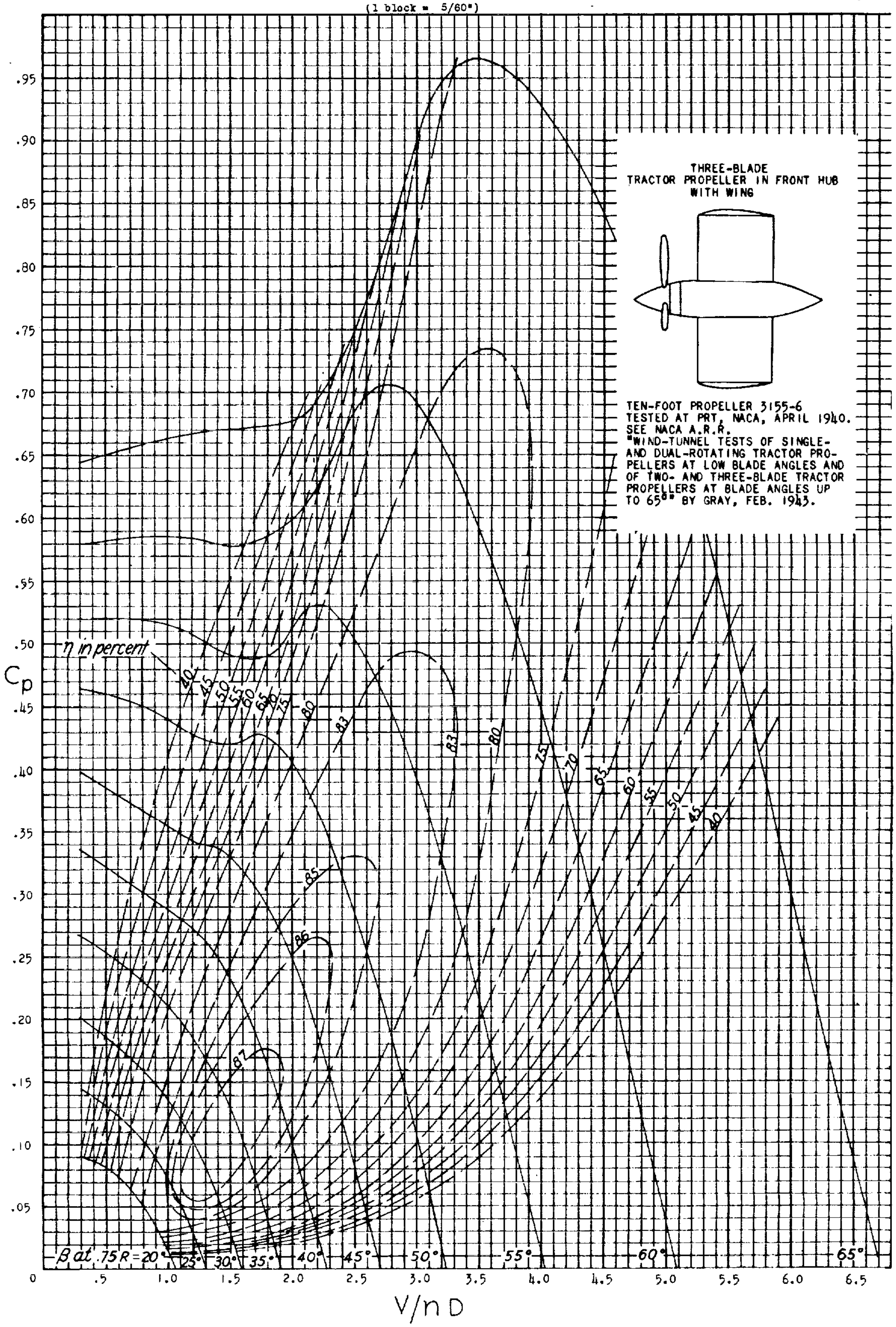
THREE-BLADE
TRACTOR PROPELLER IN FRONT HUB
WITHOUT WING
TEN-FOOT PROPELLER 3155-6
TESTED AT PRT, NACA, APRIL 1940.
SEE NACA A.C.R.
"FULL-SCALE TESTS OF SEVERAL PROPELLERS EQUIPPED WITH SPINNERS, CUFFS, AIRFOIL AND ROUND SHANKS, AND NACA 16-SERIES SECTIONS" BY BIERMANN, HARTMAN, AND PEPPER, OCT. 1940.
Cp
η in percent
β at .75 R = 20°
25°
30°
35°
40°
45°
50°
55°
60°
65°
V/nD

L-286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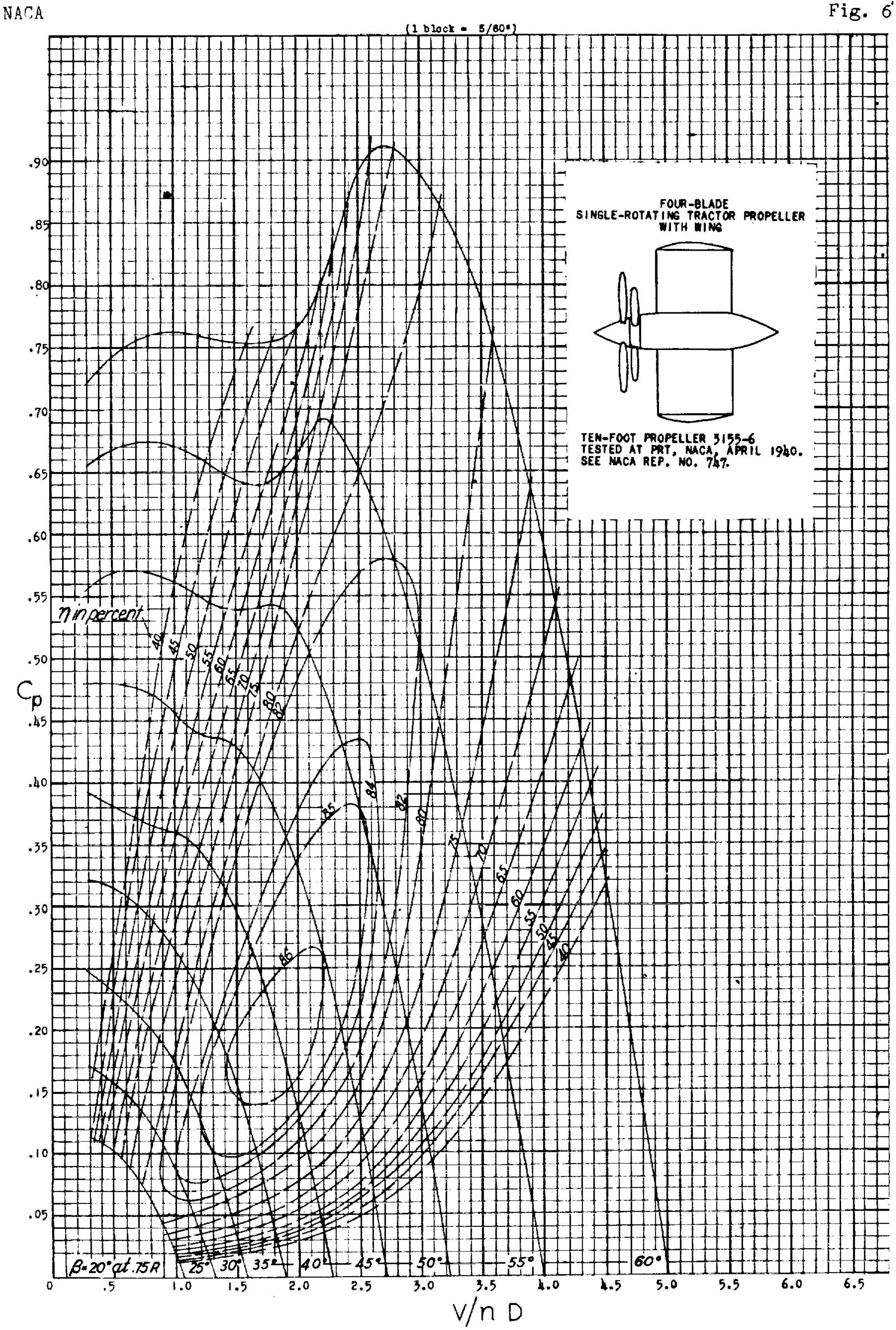
THREE-BLADE TRACTOR PROPELLER IN FRONT HUB WITH WING
TEN-FOOT PROPELLER 3155-6 TESTED AT PRT, NACA, APRIL 1940. SEE NACA A.R.R. "WIND-TUNNEL TESTS OF SINGLE- AND DUAL-ROTATING TRACTOR PROPELLERS AT LOW BLADE ANGLES AND OF TWO- AND THREE-BLADE TRACTOR PROPELLERS AT BLADE ANGLES UP TO 65°" BY GRAY, FEB. 1943.
η in percent
Cp
V/nD
β at .75R = 20°
25°
30°
35°
40°
45°
50°
55°
60°
65°

L-786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FOUR-BLADE
SINGLE-ROTATING TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLER 5155-6
TESTED AT PRT, NACA, APRIL 1940.
SEE NACA REP. NO. 747.
η in percent
Cp
V/n D
β=20° at .75R
25°
30°
35°
40°
45°
50°
55°
60°
.90
.85
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0
.5
1.0
1.5
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4.0
4.5
5.0
5.5
6.0
6.5

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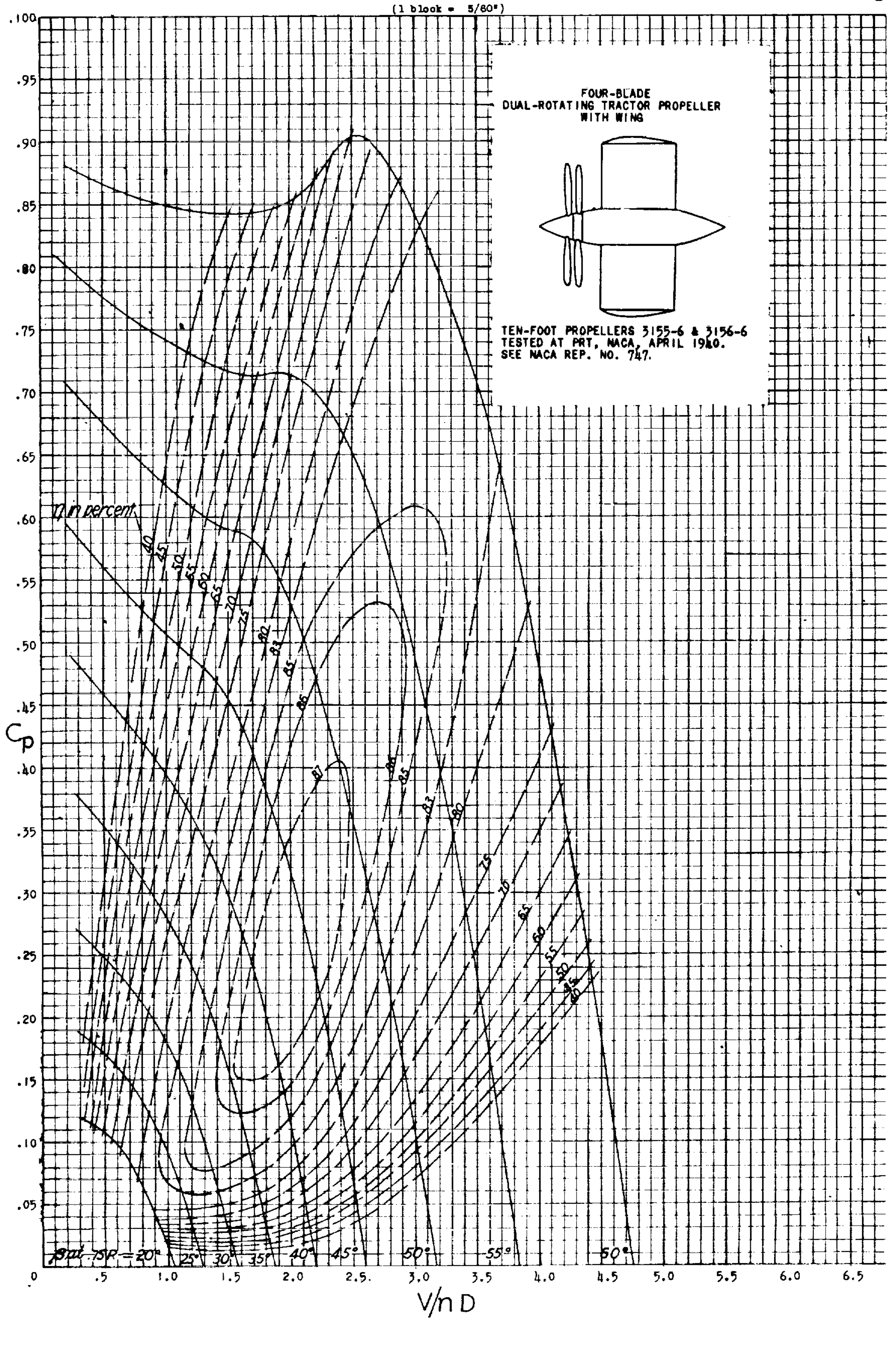
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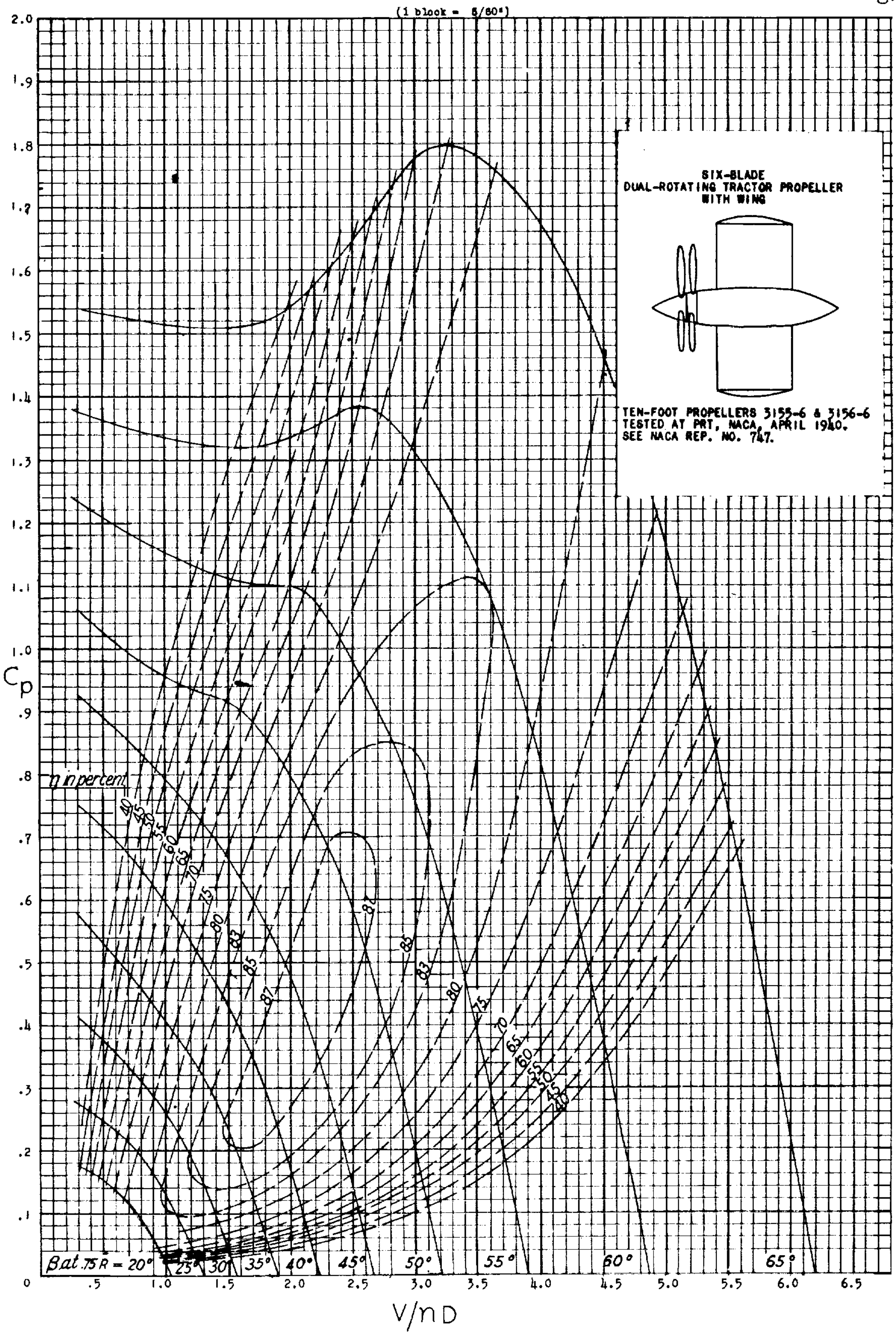
FOUR-BLADE
DUAL-ROTATING TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLERS 3155-6 & 3156-6
TESTED AT PRT, NACA, APRIL 1940.
SEE NACA REP. NO. 747.
η in percent
Cp
V/nD
β at .75R = 20°
25°
30°
35°
40°
45°
50°
55°
60°

982 - 7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DUAL-ROTATING TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLERS 3155-6 & 3156-6
TESTED AT PRT, NACA, APRIL 1940.
SEE NACA REP. NO. 747.
C_p
V/nD
η in percent
β at .75R = 20°
25°
30°
35°
40°
45°
50°
55°
60°
65°

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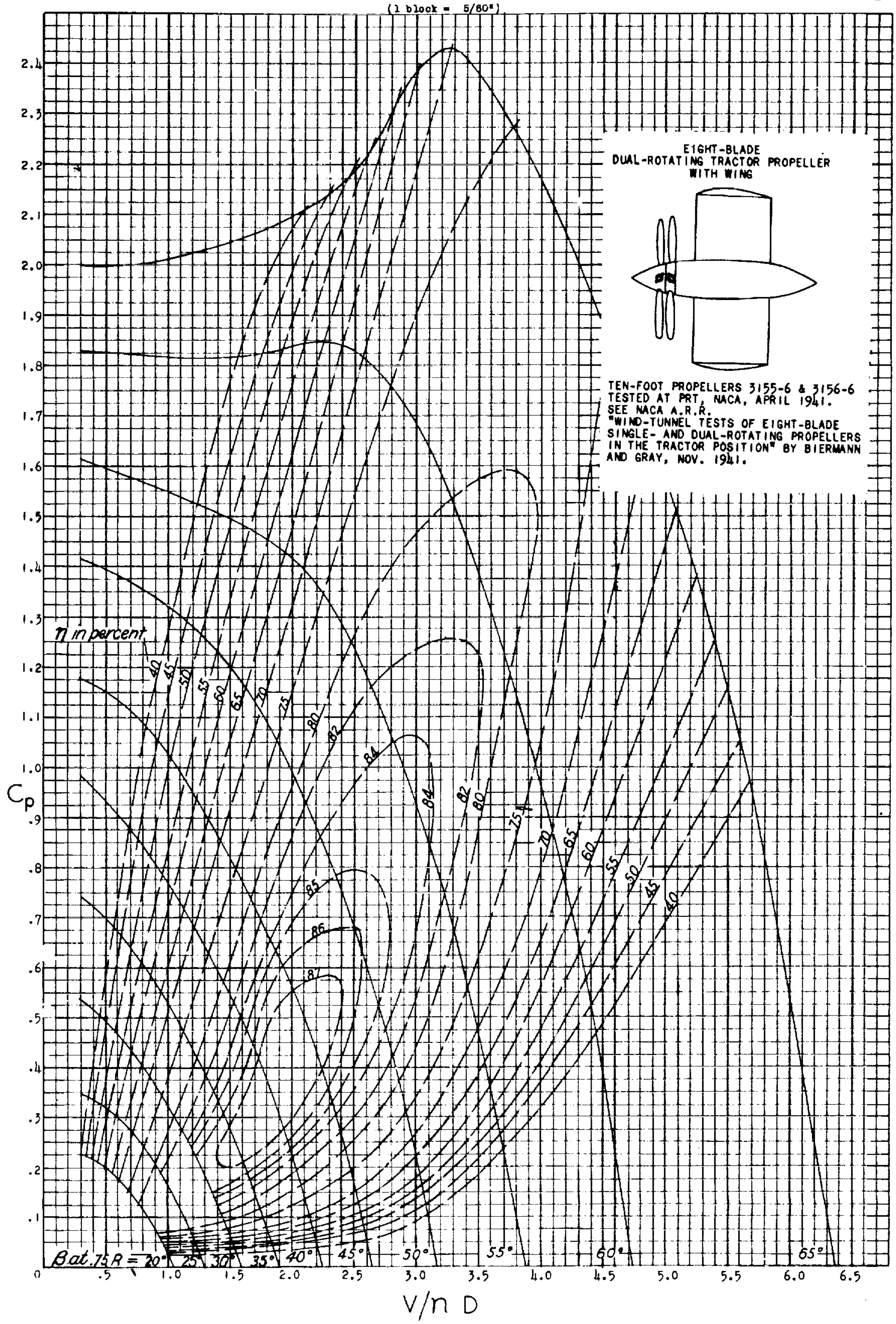
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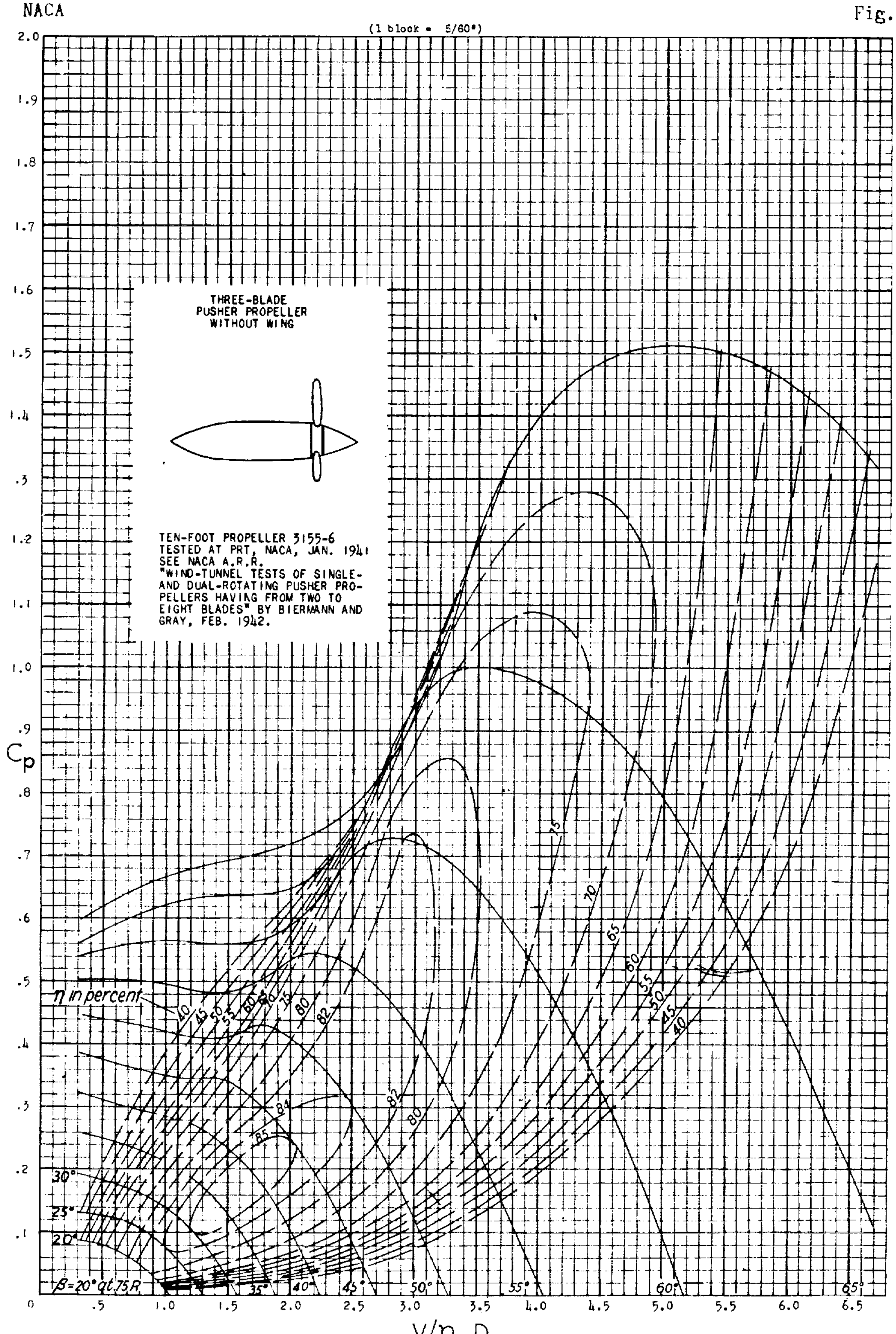
DUAL-ROTATING TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLERS 3155-6 & 3156-6
TESTED AT PRT, NACA, APRIL 1941.
SEE NACA A.R.R.
"WIND-TUNNEL TESTS OF EIGHT-BLADE
SINGLE- AND DUAL-ROTATING PROPELLERS
IN THE TRACTOR POSITION" BY BIERMANN
AND GRAY, NOV. 1941.
η in percent
β at .75R = 20° 25° 30° 35° 40° 45° 50° 55° 60° 65°
Cp
V/nD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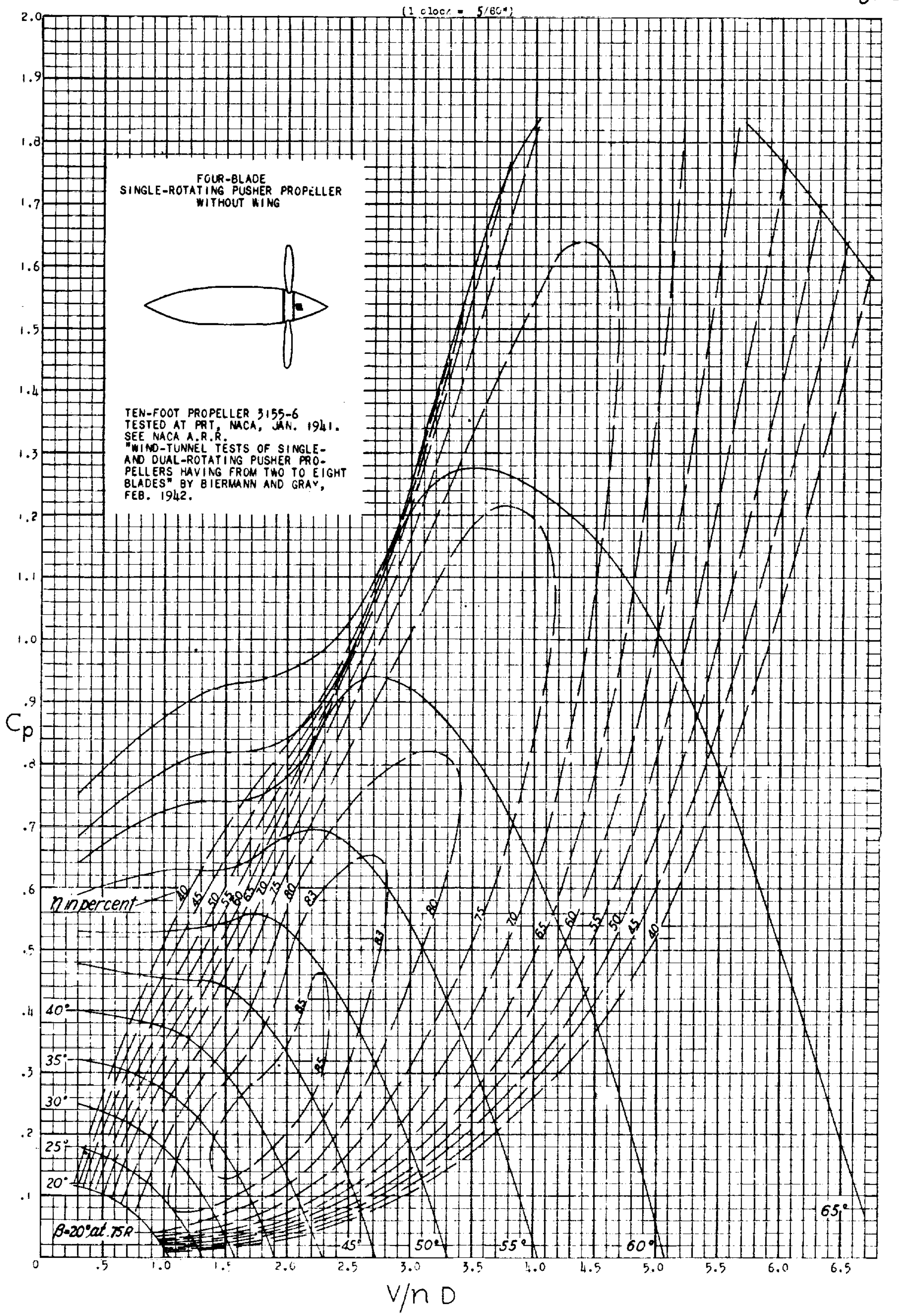
THREE-BLADE
PUSHER PROPELLER
WITHOUT WING
TEN-FOOT PROPELLER 3155-6
TESTED AT PRT, NACA, JAN. 1941
SEE NACA A.R.R.
"WIND-TUNNEL TESTS OF SINGLE-
AND DUAL-ROTATING PUSHER PRO-
PELLERS HAVING FROM TWO TO
EIGHT BLADES" BY BIERMANN AND
GRAY, FEB. 1942.
C_p
V/nD
η in percent
β=20° at .75R
20°
25°
30°
35°
40°
45°
50°
55°
60°
65°

L-286


(1 clock = 5/60")
FOUR-BLADE
SINGLE-ROTATING PUSHER PROPELLER
WITHOUT WING
TEN-FOOT PROPELLER 3155-6
TESTED AT PRT, NACA, JAN. 1941.
SEE NACA A.R.R.
"WIND-TUNNEL TESTS OF SINGLE- AND DUAL-ROTATING PUSHER PROPELLERS HAVING FROM TWO TO EIGHT BLADES" BY BIERMANN AND GRAY, FEB. 1942.
η in percent
β=20° at .75R
Cp
V/nD

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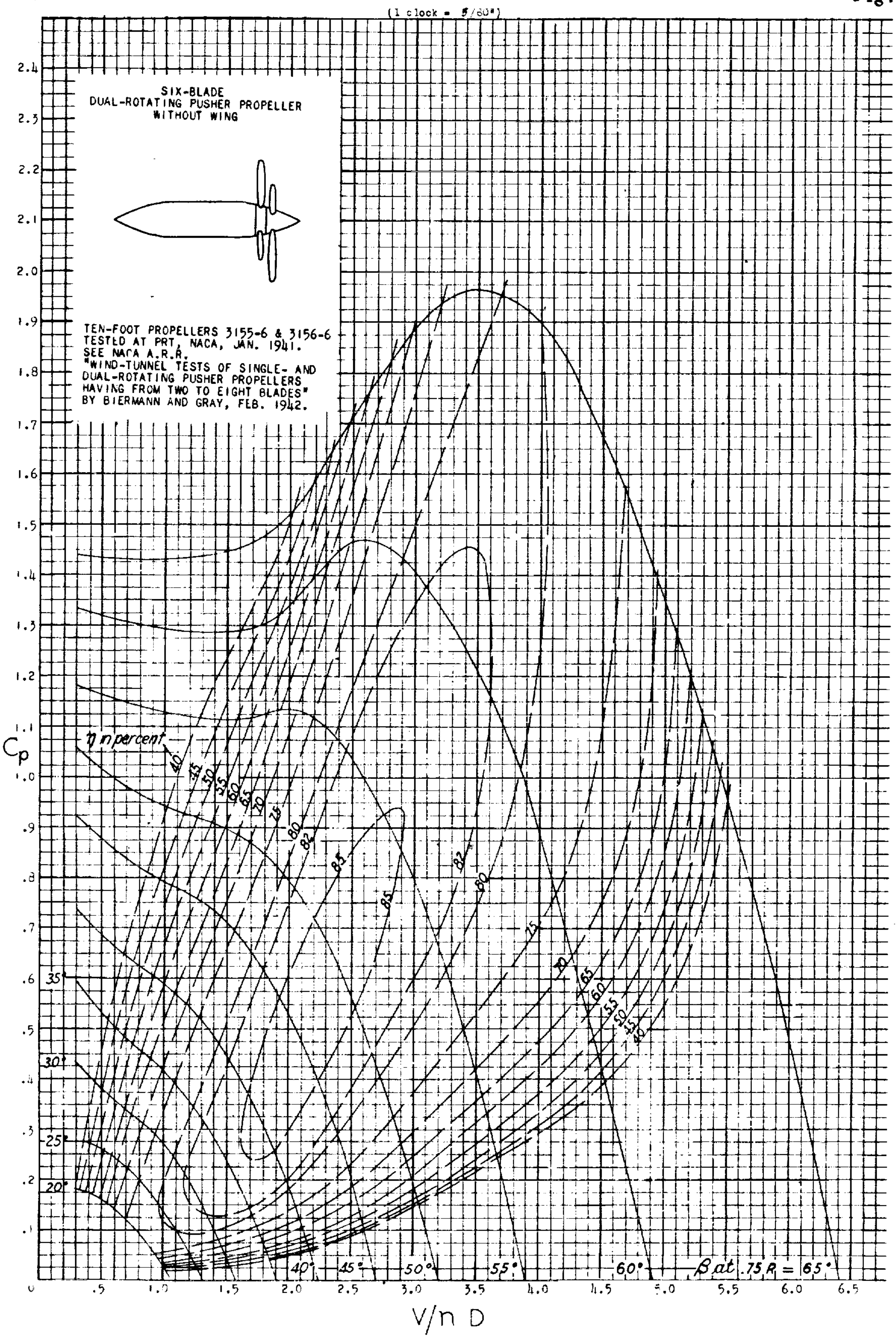
SIX-BLADE
DUAL-ROTATING PUSHER PROPELLER
WITHOUT WING
TEN-FOOT PROPELLERS 3155-6 & 3156-6
TESTED AT PRT, NACA, JAN. 1941.
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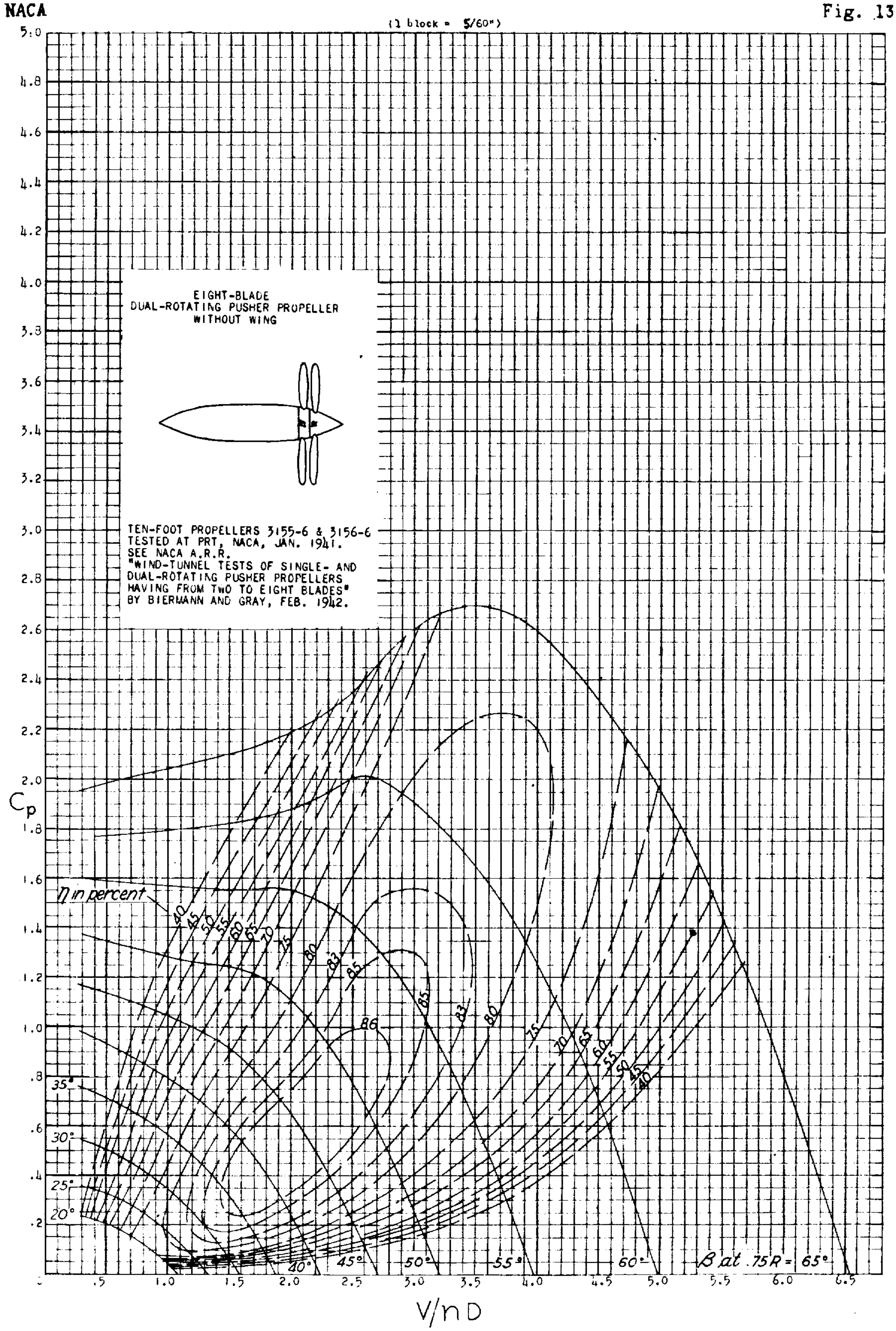
HAVING FROM TWO TO EIGHT BLADES"
BY BIERMANN AND GRAY, FEB. 1942.
η in percent
β at .75 R = 65°
C_p
V/n D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EIGHT-BLADE
DUAL-ROTATING PUSHER PROPELLER
WITHOUT WING
TEN-FOOT PROPELLERS 3155-6 & 3156-6
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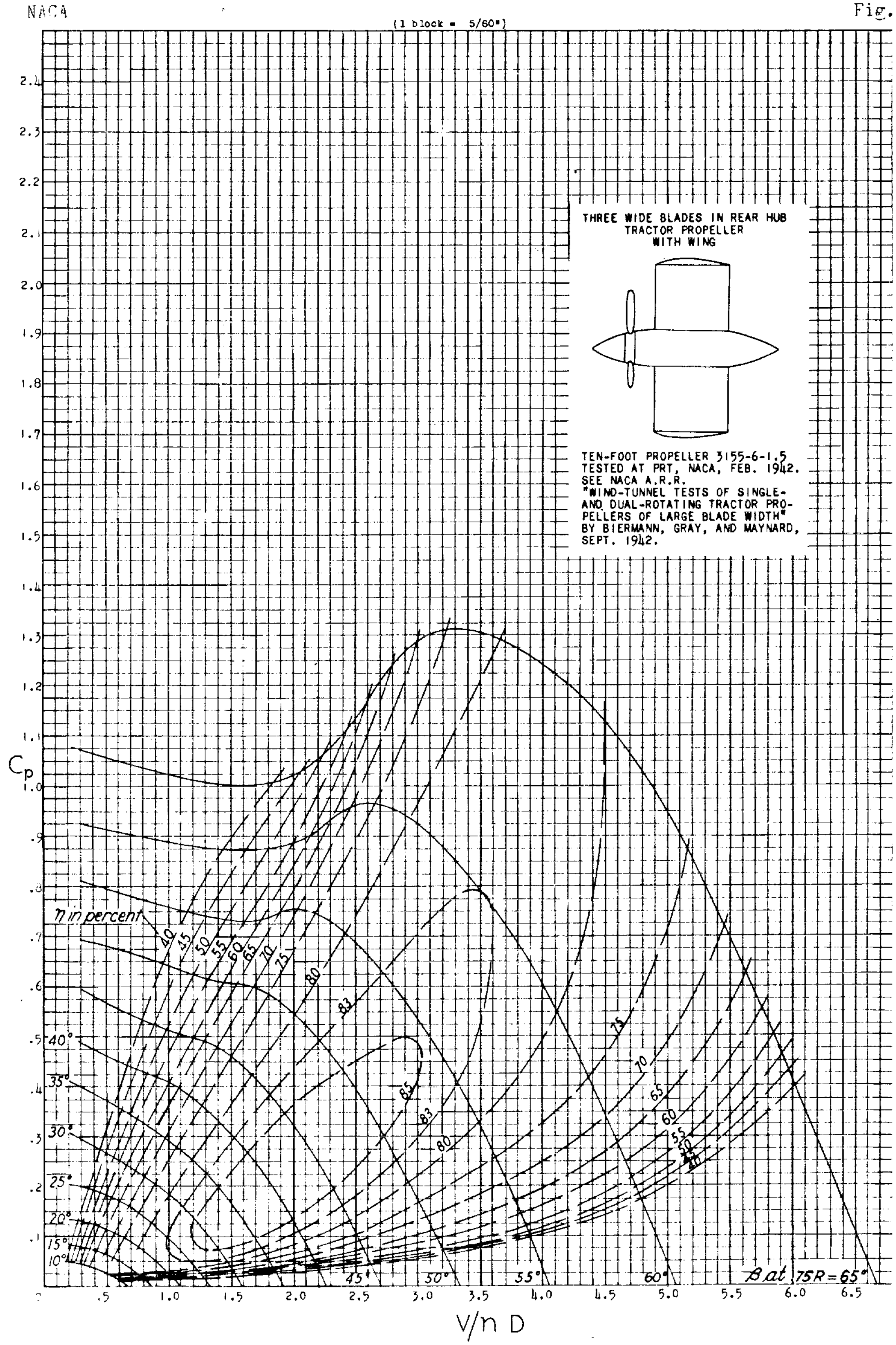
η in percent
β at .75R = 65°
Cp
V/nD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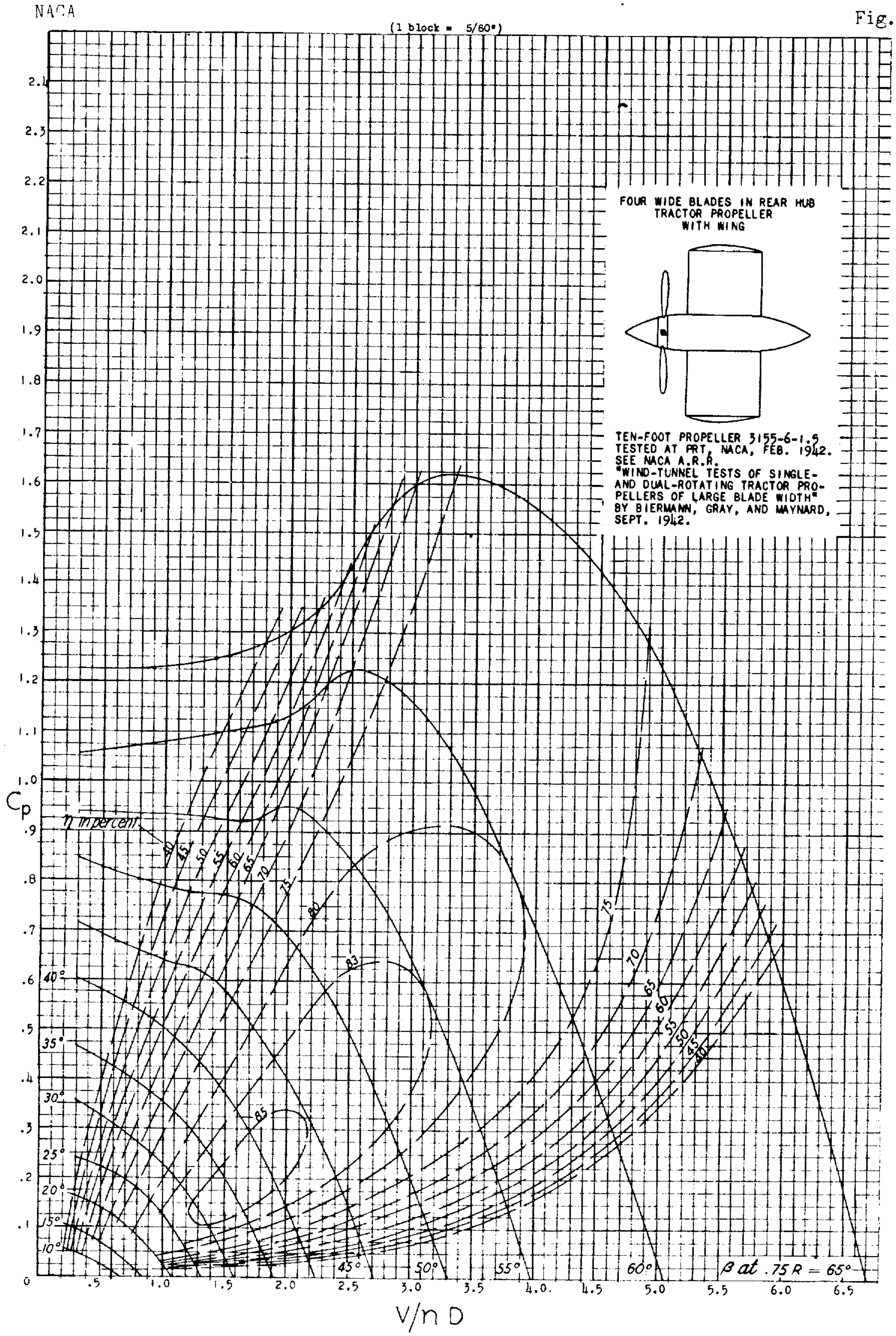
THREE WIDE BLADES IN REAR HUB
TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLER 3155-6-1.5
TESTED AT PRT, NACA, FEB. 1942.
SEE NACA A.R.R.
"WIND-TUNNEL TESTS OF SINGLE-AND DUAL-ROTATING TRACTOR PROPELLERS OF LARGE BLADE WIDTH"
BY BIERMANN, GRAY, AND MAYNARD,
SEPT. 1942.
Cp
η in percent
β at .75R = 65°
V/nD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FOUR WIDE BLADES IN REAR HUB
TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLER 3155-6-1.5
TESTED AT PRT, NACA, FEB. 1942.
SEE NACA A.R.R.
"WIND-TUNNEL TESTS OF SINGLE- AND DUAL-ROTATING TRACTOR PROPELLERS OF LARGE BLADE WIDTH"
BY BIERMANN, GRAY, AND MAYNARD,
SEPT. 1942.
Cp
η in percent
β at .75 R = 65°
V/n D

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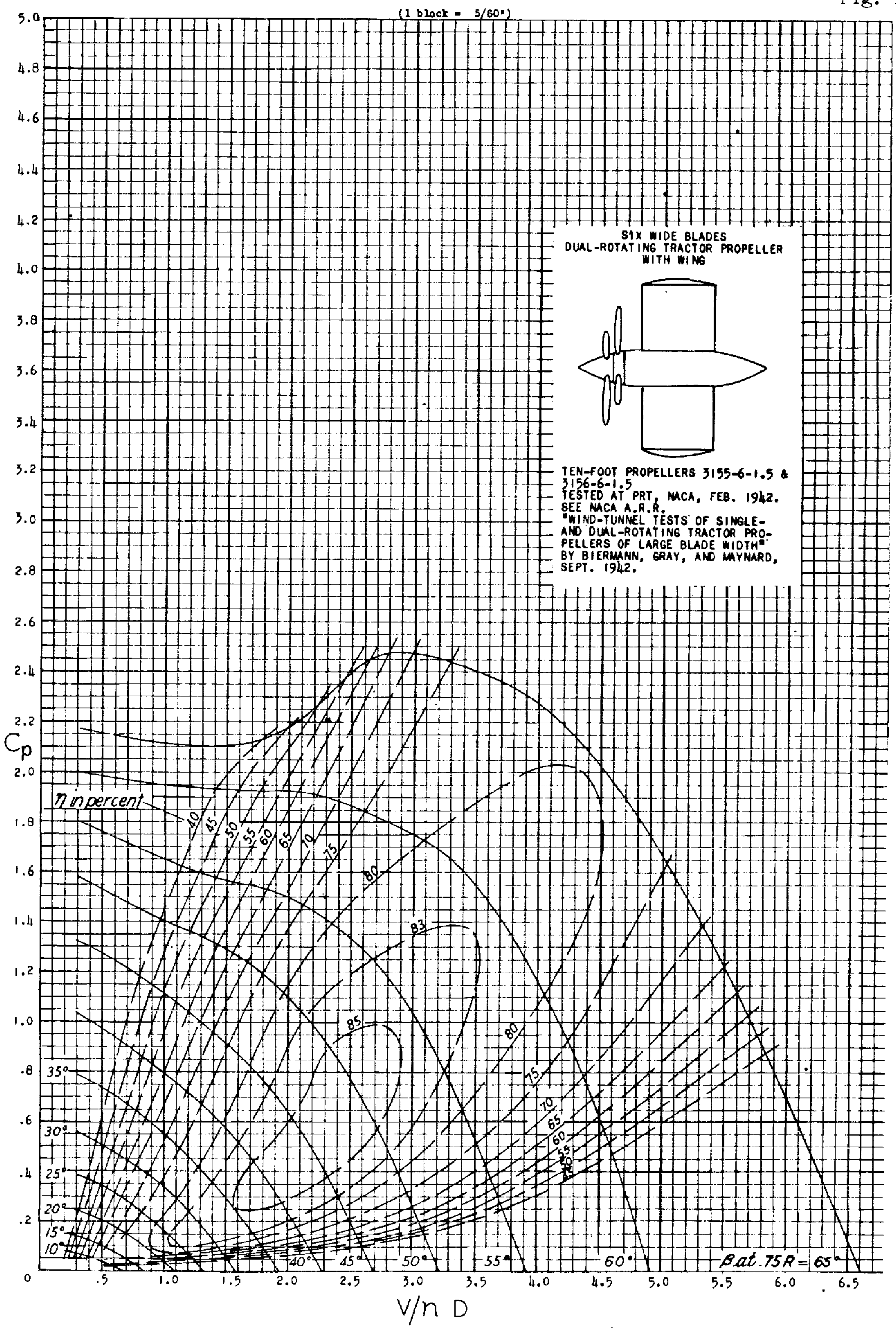
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SIX WIDE BLADES
DUAL-ROTATING TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLERS 3155-6-1.5 & 3156-6-1.5
TESTED AT PRT, NACA, FEB. 1942.
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"WIND-TUNNEL TESTS OF SINGLE- AND DUAL-ROTATING TRACTOR PROPELLERS OF LARGE BLADE WIDTH"
BY BIERMANN, GRAY, AND MAYNARD, SEPT. 1942.
η in percent
C_p
V/n D
β at .75R = 65°
10°
15°
20°
25°
30°
35°
40°
45°
50°
55°
60°
40
45
50
55
60
65
70
75
80
83
85
0
.5
1.0
1.5
2.0
2.5
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3.5
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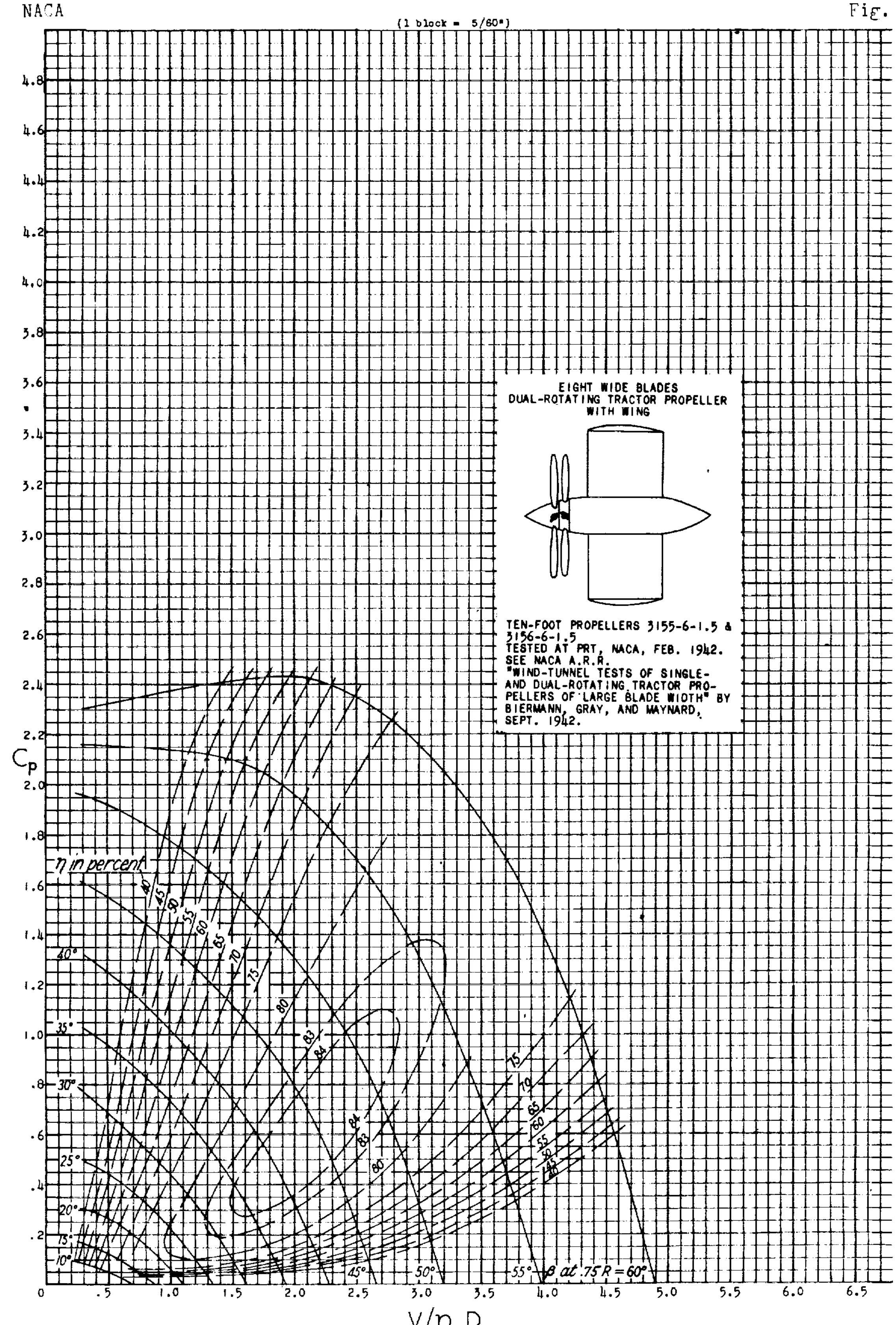
(1 block = 5/60")
EIGHT WIDE BLADES
DUAL-ROTATING TRACTOR PROPELLER
WITH WING
TEN-FOOT PROPELLERS 3155-6-1.5 & 3156-6-1.5
TESTED AT PRT, NACA, FEB. 1942.
SEE NACA A.R.R.
"WIND-TUNNEL TESTS OF SINGLE- AND DUAL-ROTATING TRACTOR PROPELLERS OF LARGE BLADE WIDTH" BY BIERMANN, GRAY, AND MAYNARD, SEPT. 1942.
η in percent
β at .75 R = 60°
C_p
V/n D